

Surgical treatment of tachyarrhythmias due to postinfarction left ventricular aneurysm with endoaneurysmorrhaphy and cryoablation [☆]

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Abstract

Objective: In this study, the efficacy of left ventricular (LV) endoaneurysmorrhaphy and cryoablation without intraoperative electrophysiologic mapping was evaluated in patients with postinfarction LV aneurysm and sustained ventricular tachycardia (VT). **Methods:** A prospective study was performed on all patients operated with malignant VT in the presence of a resectable LV aneurysm between July 1990 and February 2001. **Results:** The study included 31 patients, 20 men and 11 women, with a mean age of 65.5 years (47–84). Monomorphic, polymorphic VT or ventricular fibrillation was present in all patients prospectively, and VT was incessant in 11. Twenty-six patients had an anterior, four patients had an inferior and one patient a posterolateral myocardial wall infarction. All patients had a well-limited ventricular aneurysm. Ten patients had three, eight patients two and 13 patients had single vessel coronary artery disease. Mean preoperative ejection fraction was $34.8 \pm 14.5\%$ (8–62) and mean end-diastolic volume index was 141.5 ± 51.8 ml/m² (57–288). Six patients had mitral regurgitation grade III or IV. All patients underwent extensive cryoablation at the transition zone of scar and viable tissue and LV remodelling with prosthetic patch in 26 patients. Associated procedures were CABG in 19 patients (61%) and mitral valve reconstruction in six patients (19%). Postoperative electrophysiologic study (EPS) revealed freedom from VT induction in 25 patients and inducible VT in five patients. One patient had inducible polymorphic VT. Five patients received an implantable cardioverter defibrillator (ICD) and three patients had a permanent pacemaker implanted. After a mean follow-up of 30 ± 27 months (6–132) there was one arrhythmia-related death. There was one early hospital readmission for clinical VT and no need for late ICD implantation. **Conclusions:** In patients suffering from ventricular arrhythmias in the presence of a complicated postinfarction LV aneurysm, combined ‘blind’ cryoablation and endoaneurysmorrhaphy offers excellent arrhythmia control and clinical and haemodynamic outcome. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Cryoablation; Ventricular tachycardia; Left ventricular aneurysm; Sudden death; Myocardial infarction

1. Introduction

Aggressive thrombolytic therapy and percutaneous recanalization procedures have markedly changed the consequences of acute occlusion of a coronary artery [1]. The number of patients developing massive myocardial infarction has decreased as well as the incidence of left ventricular (LV) aneurysm. Because of this and also because other techniques and devices (radiofrequency ablation and implantable cardioverter defibrillator (ICD)) have become available, the number of patients considered for surgical

treatment of postinfarction sustained ventricular tachycardia (VT) has decreased. Only a limited number of centres around the world are performing arrhythmia surgery. However, for a number of patients surgical ablation combined with aneurysm resection and myocardial revascularization remains a possible curative procedure [2,3]. Among several surgical procedures, two major approaches have become prevalent: (1) ablation or resection of arrhythmogenic foci after precise localization by intraoperative mapping [7–9] and (2) extensive ablation procedures without mapping [2–4,10–13,20]. In contrast to previous reports detailing the importance of intraoperative mapping, series of visually guided resections or extended cryoablation without mapping achieved results similar to those obtained with map-guided procedures [4,10,11,14,20]. In this study, we aimed to evaluate the efficacy of endoaneurysmorrhaphy

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combined with blind cryoablation in the borderzone between healthy and scar tissue.

2. Patients and methods

Starting from July 1990 until February 2001, 107 patients were operated for postinfarction LV aneurysm. Ventricular arrhythmia was the major indication in 31 patients. There were 20 men and 11 women with a mean age of 65.5 years (47–84). The preoperative study protocol included a 24 h Holter electrocardiogram (ECG), echocardiography, cardiac catheterization, coronary angiography and electrophysiologic study (EPS). Twenty-six patients had anterior, four patients had inferior and one patient had a lateral wall aneurysm. Thirteen patients had single, eight patients had double and ten patients had triple vessel disease. Mean preoperative ejection fraction was $34.8 \pm 14.5\%$ (8–62) and mean end-diastolic volume index was $141.5 \pm 51.8 \text{ ml/m}^2$ (57–288). Most of the patients had concomitant symptoms of dyspnea and/or angina, 12 patients had severe angina and 13 patients had concomitant dyspnea; five of them presented severe clinical symptoms of heart failure. Only two patients were New York Heart Association (NYHA) class I for dyspnea. Twelve patients were Class II, 12 Class III and five patients were NYHA class IV. Arrhythmia-related symptoms were palpitations in five patients, presyncope in five and syncope in nine patients. Incessant VT and/or electrical storm was the major indication in eight patients and five patients needed cardiopulmonary resuscitation as their first clinical manifestation of ventricular arrhythmia. Preoperative EPS revealed non-sustained monomorphic VT in one patient, sustained monomorphic VT in 25 patients, polymorphic VT in three patients, ventricular flutter in one and ventricular fibrillation in one patient. Four subgroups were identified in function of their clinical VT and the time after myocardial infarction (less or more than 2 months after myocardial infarction) (Table 1).

Four patients required preoperative endotracheal intubation and four patients had an intra-aortic balloon pump (IABP) inserted. Three patients had previously ICD implantation and were referred with incessant VT and electrical storm not responding to an association of two or three antiarrhythmic drugs. Three patients were referred for urgent screening for orthotopic heart transplantation.

2.1. Operative technique

All patients received temazepam (2.5 mg) the evening before and 1 h prior to surgery. On arrival in the operating room (OR), standard monitoring devices were placed, with additional arterial and central venous pressure (CVP) monitoring and/or pulmonary artery (PA) catheter placement if indicated. After preoxygenation (O_2 8 l/min for 3 min), anaesthesia was induced with diazepam (0.1 mg/kg), sufentanil (4 $\mu\text{g/kg}$), rocuronium (0.5 mg/kg), and maintained thereafter using the same drugs. After endotracheal intubation, mechanical ventilation was started (Anesthesia Delivery Unit, Datex-Ohmeda, Helsinki, Finland). Peroperative transoesophageal echocardiography was used in all patients. All patients were operated via median sternotomy. Cardiopulmonary bypass was started via cannulation of the ascending aorta and right atrium or both venae cavae in case of mitral valve reconstruction. Core temperature was lowered to $\pm 32^\circ \text{C}$ and the aorta crossclamped. Continuous antegrade warm potassium cardioplegia was given at a volume of $\pm 150 \text{ cm}^3/\text{min}$. After aneurysmectomy the LV cavity was explored and thrombotic material removed. The transition zone of viable and scar tissue was cryoablated as described by Guiraudon et al. [2]. Cryoablation was performed with a Frigtronics cryosurgical system CCS 100 (CooperSurgical Inc, Shelton, CT, USA). A 15 mm probe cooled to -60°C was used for 2 min for each lesion. The probe was applied along the limits of the endocardial fibrosis; each application overlapped the preceding one to attain continuous encircling cryoablation. On the ventricular septum care was taken to avoid ablation in the upper part of the septum near its membranous portion, in order to prevent His bundle block. An average of 14 ± 2.8 (11–18) applications was used for each patient extending the aortic crossclamp time with 25–30 min. Scar tissue present at the papillary muscles was also cryoablated.

Remodelling of the LV cavity was performed with an intracavitary patch as described by Cooley et al. [15]. For this technique an elliptical patch made of dacron or gluteraldehyde fixed pericardium is used. Long and short axis diameter varies from 3–4 to 2–3 cm, respectively. The patch is anchored with a running 2–0 prolene suture starting deep on the interventricular septum at the edge of the scar tissue. The delineation zone between the scar and healthy tissue is used to guide the fixation of the patch on the other

Table 1
Patient subgroup characteristics in function of the clinical VT status and time after MI^a

Group	Clinical data	Patient number	Infarct location		Mean EF (%)	LVEDVI (ml/m ²)
			Anterior	Inferior		
I	Incessant VT, <2 months after MI	7	7	0	24.2	156
II	Incessant VT, >2 months after MI	4	3	1	37.2	137
III	Sustained VT, <2 months after MI	3	1	2	32	150
IV	Sustained VT, >2 months after MI	17	15	2	38	98

^a EF, ejection fraction; LVEDVI, left ventricular end-diastolic volume index; MI, myocardial infarction; VT, ventricular tachycardia.

areas of the LV cavity. The patch has always to be fixed under the ventriculotomy and will be less deep at the lateral wall where the scar tissue is usually less marked and extended. The LV wall is closed over the patch after disconnection of cardiopulmonary bypass and protamine administration. Foreign material strips like teflon are not necessary to close the ventriculotomy. Additional CABG and or mitral valve reconstruction was performed after the cryosurgery and LV repair. The mitral valve was approached via an incision behind the interatrial groove. Two ventricular and two atrial pacing wires were used in each patient.

2.2. Postoperative protocol

EPS, 24 h Holter ECG, and echocardiography were performed in all patients at postoperative days 8–10. Results of EPS were considered abnormal if VT (>30 s) was inducible using up to three extra stimuli during their basic pacing cycle length. Electrical success was defined by normal EPS and Holter ECG results during the postoperative period. Clinical success was defined by the absence of spontaneous VT during hospital stay and during regular follow-up in the outpatient clinic. Postoperatively, no antiarrhythmic drugs were given in order to evaluate the early postoperative result of the surgical procedure. Oral anticoagulants were started for 3 months.

3. Results

In all 31 selected patients cryoablation procedure could be performed. LV endoaneurysmorrhaphy was required in 26 patients and direct closure of the LV scar was performed in five patients (three inferior, one anterior and one lateral wall aneurysm). Remodelling of the left ventricle was sufficient with the exclusion of the inferior and lateral aneurysms; in one patient there was only a limited apical anterior aneurysm not requiring insertion of an intracavitary patch. Myocardial revascularization with one to four grafts was performed in 19 patients (61%) and the left internal thoracic artery was used in 16 patients. CABG was not performed in two patients with inferior infarct, in three patients the LAD was considered inoperable, in three patients the LAD was explored and found to be completely thrombosed. Two patients presented only with 50% stenosis and one patient had a lesion of the distal 1/3 of the LAD.

Mitral valve reconstruction was necessary in six patients (19%). All patients presented with annular dilatation and one patient presented with chordal rupture of P3. Carpentier–Edwards annuloplasty rings size 30 and 32 were used in order to obtain restrictive annuloplasty and adequate leaflet coaptation. Mean crossclamp time was 84 min \pm 30 (44–177 min) and mean perfusion time was 130 min \pm 47 (64–258 min).

All patients survived the procedure. Low cardiac output required insertion of an IABP in one patient and an Abiomed biventricular assist device in another patient.

Hospital mortality was 6.5% (two patients) due to low cardiac output, including the patient with the Abiomed ventricular assist device.

Postoperative EP testing was performed in 30 patients. Monomorphic VT was inducible in five patients (16%) and ICD implantation was carried out. There was clinical recurrence of polymorphic VT in one patient who ultimately died. Mean ejection fraction and LV end-diastolic volume index of patients who were not inducible and inducible were 37.2% and 144 ml and 22.6% and 144 ml, respectively. Three patients had dual chamber pacemaker implantation, one for complete AV block and two for sinus node dysfunction.

Patients were followed on a regular basis at the EP outpatient clinic of our centre or by the referring cardiologist. Mean follow-up is 30 months (5.7–132 months). Functional evaluation shows 11 patients in NYHA class I, 15 patients in NYHA class II and one patient in NYHA class III. This patient is on the waiting list for orthotopic heart transplantation. There are two late deaths (6.5%). One patient died from an adenocarcinoma of the lung 5 years after surgery. The other patient died suddenly 3 years and 5 months postoperatively. This has to be considered as an arrhythmogenic death. There was one early recurrence of sustained VT in a patient with a postoperative implanted ICD and amiodarone was started. The four other patients with postoperative ICD implantation did not present clinical or ICD documented VT. Five patients received early postoperative class III antiarrhythmic drugs, three because of inducible VT together with ICD implantation and two because of atrial fibrillation. The medical treatment was stopped in two patients with early postoperative inducible VT after a period of 3 months. There was no further need for ICD implantation. Clinical results of the subgroups I–IV are represented in Table 2. Patients operated on, less than 2 months after myocardial infarction, independent of their clinical VT status, had lower ejection fraction, larger LVEDVI, higher early mortality and higher incidence of assist device and ICD implantation.

Actuarial survival, actuarial rate of freedom from clinical VT and ICD implantation is represented in Figs. 1–3, respectively.

4. Discussion

Direct surgery for the treatment of VT is performed less frequently in the last years due to improved methods aiming at reducing LV myocardial damage in the acute phase of myocardial infarction [5] and the better medical treatment of consequent heart failure and associated tachyarrhythmias. Availability of ICD alone or combined with resynchronisation therapy [16] and improved catheter based mapping and ablation techniques increased the treatment modalities in patients with postinfarction ventricular arrhythmias and decreased LV function. However, this study shows that there is a subset of patients who still will

Table 2
Clinical results of patient subgroups in function of VT status and time after MI^a

Group	Clinical data	Mortality		Assist device		ICD implantation	
		Early	Late	Preoperative	Postoperative	Preoperative	Postoperative
I	Incessant VT, <2 months after MI	1	–	3 IABP	1 IABP, 1 Abiomed	–	2
II	Incessant VT, >2 months after MI	–	–	1 IABP	–	2	1
III	Sustained VT, <2 months after MI	1	–	–	–	–	1
IV	Sustained VT, >2 months after MI	–	–	–	–	1	1

^a IABP, intra-aortic balloon pump; MI, myocardial infarction; ICD, implantable cardioverter defibrillator; VT, ventricular tachycardia.

clearly benefit from the combined treatment of cryoablation and repair of associated cardiac lesions.

In young patients with sustained VT, ICD implantation remains a mere palliative treatment, even with the currently, extremely low morbidity and mortality rates. The prospect of lifelong ICD treatment is an economic, financial and social burden for this young patient group due to withdrawal of driving licence and working permit [17]. In addition, *early remodelling* of the left ventricle will have a positive effect on long-term haemodynamics and survival [6,19]. Endoaneurysmorrhaphy repair seems to have better long-term results than simple linear closure [19].

Another subset of patients is the group who presents with incessant VT. Catheter ablation or direct surgery is the only option. This small group of patients is usually younger, presents with a recent large anterior wall myocardial infarction and unstable haemodynamics. Extensive loss of myocardial tissue and rapid evolution to a large aneurysm decreases the cardiac reserve in these patients who also often receive a large amount of cardiodepressive antiarrhythmic drugs. In our series we operated seven patients in very unstable haemodynamic and electrical conditions. They all presented extremely low EF and abnormal LVEDVI. The therapeutic choice is between direct combined surgery or implantation of a left or biventricular assist device with the option for bridge to recovery or bridge to transplantation. In our series one patient remained in low cardiac output requiring implantation of a biventricular

assist device. The patient finally expired from infectious complications. Although the initial antiarrhythmic results in these patients were less optimal compared to patients without incessant VT, it became clear that the midterm results were very satisfactory without any clinical arrhythmia recurrence in this subgroup of patients.

The results with cryoablation seem to be more favourable in patients with incessant VT within 2 months after myocardial infarction as compared to endocardial resection. The results of Bourke et al. [18] using endocardial resection demonstrated a higher mortality and late arrhythmia recurrence.

Finally, the third subgroup of patients who will benefit from direct surgery is the patient cohort presenting with recurrent sustained or incessant VT despite previous ICD implantation. In our series three patients were submitted successfully to direct surgery 2, 9 and 82 months after ICD implantation. Catheter ablation was not possible or unsuccessful in treating the tachycardia in these patients.

As our experience started with patients suffering from incessant VT, we preferred to submit these patients to the shortest cardiopulmonary bypass time as possible. Encouraged by the excellent results of Guiraudon et al. [2,11] we decided not to use peroperative mapping in this difficult patient group and to use extended blind cryoablation. The excellent early results and the technical simplicity with encircling cryoablation were the reasons not to use sequential mapping even in stable patients. The clinical results of

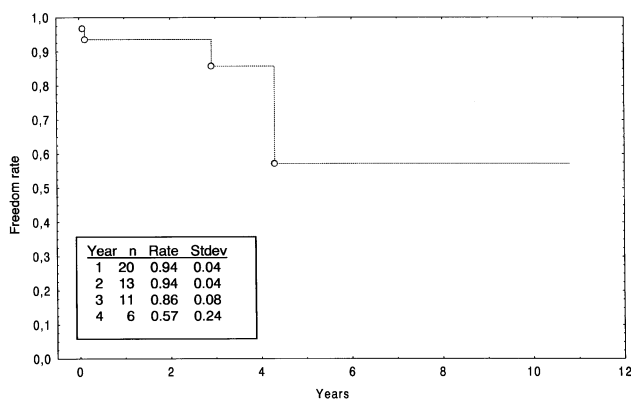


Fig. 1. Kaplan–Meier overall survival curve (early mortality included).

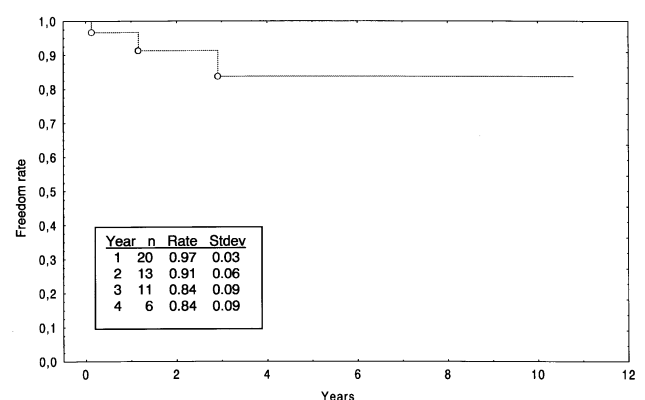


Fig. 2. Kaplan–Meier actuarial rate of freedom from clinical VT.

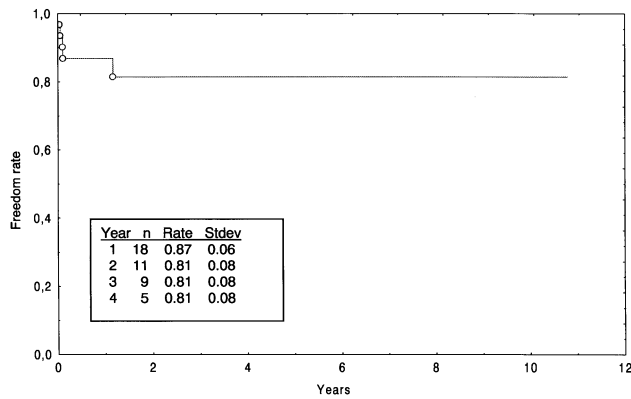


Fig. 3. Kaplan–Meier actuarial rate of freedom from ICD implantation.

Guiraudon et al. [2], Frapier et al. [3] and our actual experience are comparable with the results of other groups using peroperative mapping procedures [7–9]. Although new mapping techniques like return cycle mapping described by Nitta et al. [21] could be more accurate and less time consuming in the clinical setting, discussion will remain if peroperative mapping will finally improve the clinical results [12]. Nevertheless, large encircling cryoablation without mapping remains a very interesting tool. It is a simple surgical technique, reproducible in most of the cardiac centres where a cryosource is available, and without the need of an extended peroperative EP investigation. However, pre- and postoperative EP studies must be performed which makes this surgical approach inaccessible in centres without a well-functioning EP laboratory. Careful patient selection is the key to long-term success and patients selected for this treatment have to be directed to an experienced surgical and electrophysiology group. Patients without a well-delineated aneurysm are best treated with other therapeutic modalities and diffuse hypokinetic or dyskinetic areas are a suboptimal substrate for direct surgery. Whatever technique used for direct VT surgery, correction of additional abnormalities has to be performed in order to obtain good long-term results [20].

Myocardial revascularization [3], mitral valve reconstruction and remodelling of the left ventricle by means of endoaneurysmorrhaphy [15] or Dor technique [20] is necessary for improved long-term electrical stability and haemodynamics. The technique used by our group is easily reproducible. It differs from the Dor technique [20] where endocardial resection forms the basis of the antiarrhythmic treatment and cryoablation serves as an adjunct to the endocardial resection or as an isolation procedure when an autologous ‘hinge’ patch is used. Because of the encouraging clinical results with this simple surgical approach, we recently introduced another algorithm for patients referred for LV aneurysm repair. A prospective EPS study is actually performed even if the patient does not present a history of clinical VT. A positive EPS indicates ‘prophylactic’ extended cryoablation. Only long-term results will demonstrate the value of this algorithm.

In conclusion, a well-selected group of patients with post-infarction LV aneurysm and clinical VT will benefit from a simplified surgical procedure including extended blind cryoablation and LV remodelling. It offers excellent arrhythmia control and very satisfactory clinical and haemodynamic outcome.

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Appendix A. Conference discussion

Mr J. Pepper (London, UK): Can I just ask you whether as a result of this analysis how do you define the aneurysm? Do you rely on angiography or do you prefer to use some more sophisticated methods, MRI? Obviously it is a crucial factor, so I wonder what you do.

Dr Wellens: Naturally we rely on the angio. We will also try to have a good TE echo, if it is possible.

Mr Pepper: A TOE echo?

Dr Wellens: Yes, because a number of these patients with incessant VT, will be intubated, and recently we tried to have an MRI scan if it is clinically possible to have these patients in the radiology department.

Dr Y. Zhang: (Beijing, China): Do you do mapping during the operation is the first question?

And the second, what is the criteria for your using cryoablation for your operation? You have very excellent operation results, but I want to know on what kind of patient do you use this treatment? Thank you.

Dr Wellens: For the first question, we don't use any perioperative mapping in the operating theater. We perform preoperative electrophysiologic mapping, if possible, otherwise, patients with incessant VT will go straight to the operating theater.

I didn't have the second and the third question. Can you repeat this?

Mr Pepper: I think he is asking why you selected cryoablation, is that right, as a technique?

Dr Zhang: Yes

Dr Wellens: We used cryoablation because it is a very good source, we know it gives excellent transmural lesions, it is very simple. Endocardial resection, mainly in incessant VT patients, gives higher early mortality and also even a lower incidence of arrhythmia-free events after the operation.

Mr Pepper: So can I just check with you, as well as the endocardial resection, you meticulously go around the perimeter of the infarcted area, yes?

Dr Wellens: Yes we encircle completely the infarcted area. If we are in the early post myocardial setting where sometimes the scar is not very well limited, we will apply a double row of cryoablation, and you always have to overlap one cryolesion with the other to have really a complete circle.

Mr Pepper: And in your experience did this result in any damage to the papillary muscles and necessitate mitral valve operation? I noticed you had mitral valve repairs, but I presume they were due to pre-existing mitral valve pathology.

Dr Wellens: Because of the presence of mitral regurgitation 3 or 4, we had to perform mitral valve repair through an incision in the left atrium, but this is the advantage of cryoablation. There are many papers, also clinical and experimentally, that cryoablation does not harm the papillary muscles. So you can use cryo this very extensively without creating post-cryo mitral valve regurgitation.